50103-522

# OPTICAL PROFILER FOR ULTRA-SMOOTH SURFACE WITH NORMAL INCIDENT BEAM DEFLECTION METHOD

## RELATED APPLICATIONS

[01] This Application claims priority to Provisional Application Serial Number 60/459,760, filed on April 1, 2003, the entire disclosure of which is herein incorporated by reference.

## FIELD OF THE INVENTION

[02] The present invention relates to the field of measuring thin films, including films provided on a disk for hard disk drives, and more particularly, to arrangements and methods for measuring the topography of an ultra-smooth surface of such a magnetic recording disk.

## BACKGROUND

[03] Coated thin film disks are used in a variety of industries. One example is the computer hard disk industry. The computer hard disk (magnetic storage device) is a non-volatile memory device that can store large amounts of data.

[04] An important specification in the design and manufacture of thin film media for hard disk drives is HMS_Wq, otherwise known as r.m.s. head-media spacing modulation. The HMS_Wq provides a measure of the spacing between a read/write head and the ultra-smooth surface of the thin film on the hard disk. An instrument currently used by designers to measure this parameter is known as the Candela profilometer. A description of such a profilometer is provided in U.S. Patent No. 6,392,749.

[05] The Candela profilometer infers the local slope of a disk surface by measuring the deflection of a collimated optical beam that is incident upon a disk surface at an oblique angle. One of the advantages of this technique is that it is affected very little by disk mode

vibrations of the spinning disk under test. However, the technique is very sensitive to proper optical alignment and is not easily portable. This limits the usefulness of the Candela profilometer.

[06] Another drawback to the arrangement provided by the Candela profilometer is that it normally measures both height and slope information. In order to obtain a measurement of just the height or the slope, special arrangements of the Candela profilometer are required, including employing multiple lasers to provide measurement signals.

[07] Another type of method of measuring HMS_Wq is with a laser doppler vibrometer (LDV). Unlike the Candela profilometer, the LDV technique is a readily portable technique. However, because the LDV technique measures out-of-plane motion, the HMS_Wq measurement is easily contaminated by disk mode vibrations.

## SUMMARY OF THE INVENTION

[08] There is a need for an optical profiler able to measure the topography of an ultra-smooth surface, such as on a hard disk, that is portable, cost-effective and capable.

[09] This and other needs are met by embodiments of the present invention which provide an apparatus for measuring surface topography of a surface comprising a linearly polarized light source that generates a light beam. Optics are provided that focus the light beam on a surface to be measured such that a normally incident beam deflection is provided. The optics include polarization optics such that the incident beam has a first polarization and a reflected beam from the surface has a second polarization different from the first polarization. A position sensitive detector is positioned to detect the reflected beam.

[10] The earlier stated needs are also met by other aspects of the present invention which provide a method of measuring the topography of a surface comprising the steps of directing a beam of light of a first polarization towards the surface to be measured. The beam of light is directed at the surface in a direction normally incident to the surface, with a reflected beam from the surface also being normally incident to the surface. The polarization of the reflected beam is changed to a second polarization different from the first polarization. The reflected

beam with the second polarization is directed to a position sensitive detector. From the measurements taken at the position sensitive detector, the topography is determined.

[11] The earlier stated needs are met by still further aspects of the present invention which provide an arrangement for measuring topography of an ultra-smooth surface comprising a source of laser light, and means for directing the laser light on the ultra-smooth surface and measuring the topography of the ultra-smooth surface.

[12] The foregoing and other features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

[13] Figure 1 depicts a schematic side view of an optical profiler constructed in accordance with embodiments of the present invention.

[14] Figure 2 depicts quadrants for a position sensitive detector on an x-y axis system.

[15] Figure 3 depicts an alternate embodiment of the optical profiler constructed in accordance with the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

[16] The present invention addresses and solves problems related to optical profiling of surfaces, such as ultra-smooth surfaces on magnetic recording disks. In particular, the present invention provides a device that is portable, cost-effective and capable. It achieves this by using a normally incident beam deflection methodology. The normally incident approach is enabled by utilizing the polarization properties of light. Accordingly, the measurement apparatus comprises relatively few optical components and is readily made into a compact and portable device. The device is useful in forming HMS_Wq measurements or any applications where topographical characterization of ultra-smooth surfaces is required.

[17] Figure 1 depicts an exemplary embodiment of an optical profiler constructed in accordance with the present invention. One of the advantages of the present invention is the

use of conventional components that are assembled to make the present invention in the manner depicted in Figures 1 and 3. This makes the arrangement very cost-effective.

[18] The optical profiler 10 in Figure 1 includes a laser light source 12 and provides a collimated beam of linearly polarized laser light 13. The laser light may have a wide variety of different wavelengths. An exemplary wavelength suitable for the use in the present invention is 650 nm. The collimated beam of linearly polarized laser light 13 is provided to a half-wave plate 14. As is well known, half-wave plates are able to change the direction of linear polarization of a polarized light beam. In the present invention, the half-wave plate 14 is aligned so that the transmitted beam 15 comprises primarily p-polarized light.

[19] A long working distance microscopic objective 16 receives the p-polarized light from the half-wave plate 14. A long working distance microscopic objective acts to convert the collimated beam 15 of p-polarized light into a converging beam 18. Convergence is such that the beam 18 is brought to a sufficiently small spot at the focal point upon the target or a test surface 28. Due to the beam 18 being arranged to be normally incident to the surface 28, this test spot on the test surface 28 may be very small, especially in comparison to arrangements in which the laser light strikes the surface at an oblique angle.

[20] After the long working distance microscopic objective 16, the converging beam 18 passes through a polarizing beam splitter 20. The p-polarized light in the converging beam 18 is transmitted by the polarizing beam splitter 20 with little reflection loss. The converging beam 18 passes through the 45 degree surface 22 of the polarizing beam splitter 20 and through a quarter-wave plate 24. The alignment of the quarter-wave plate 24 is such that the polarization of the reflected beam 26 is changed to contain only s-polarization.

[21] Since the beam 18 is normally incident upon the test surface 28, which is a highly reflective, ultra-smooth surface, the reflected beam 26 is reflected back along its original path from the focal point 29.

[22] In the embodiment of Figure 1, a 45-degree surface 22 of the polarizing beam splitter 20 is positioned to direct the reflected beam in direction perpendicular to the normal incident beam 18. A position sensitive detector 30 is positioned to detect the beam 26 reflected from the test surface 28 and the 45-degree surface 22 of the polarizing beam splitter 20. Based

upon the measurements taken at the position sensitive detector 30, a signal processor is able to determine the topography of the surface 28 in a manner more detailed below. This can be achieved by a conventional processor (not shown).

[23] Figure 2 depicts the four quadrants A, B, C and D, and the position sensitive detector 30 provides an output signal from each of these quadrants. In Figure 2, the z-direction is considered to be normal to the plane of the page. Transferring the coordinate system onto the target 29 with the set-up illustrated in Figure 1, the corresponding coordinates on the target 29 can be defined as: x and z directions are horizontal and vertical in the plane of the page, respectively. The y direction is normal to the plane of the page. For slopes whose direction normal lies in the x-z plane, the light beam 18 is deflected by the local slope of the reflecting target surface 28, causing the signal to be enhanced or depleted in the A, B and C, D quadrants. For slopes whose direction normal lies in the y-z plane, enhancement/depletion occurs in the A, D and B, C quadrants. For small slopes, the following relationships pertain:

$$m_{xz} = k_1*[(A+B)-(C+D)]/(A+B+C+D)$$

$$m_{yz} = k_2*[(A+D)-(B+C)]/(A+B+C+D)$$

wherein $k_1$ and $k_2$ are constants of proportionality between the measured signal and the local surface slope.

[24] Assuming that the surface profile is represented by f(x) in the x-direction, then df/dx = slope, where x is the distance along the measurement direction. The profile or topography of the surface 28 can be calculated by integration of the slope information, by the processor (not shown).

[25] Due to the beam's normal incidence, the signals measured by the position sensitive detector 30 contain only slope information. There is no need to provide a second laser or other measure to separate the height and slope information, as provided by known arrangements.

[26] Figure 3 shows another aspect of the present invention in which the optical arrangement is configured in a manner that allows the overall height of the device to be minimized. The same reference numerals are provided for the individual elements in Figure 3 as in the embodiment of Figure 1. However, in the embodiment of Figure 3 the laser light is

generated and directed to the polarizing beam splitter 20 in a direction that is perpendicular to the normally incident beam directed towards the surface 28. The 45-degree reflecting surface 22 of the polarizing beam splitter 20 redirects the converging beam 18 towards the surface 28 and through the quarter-wave plate 24. Instead of the reflected beam from the surface 28 being directed in a perpendicular direction to the position sensitive detector 30, the embodiment of Figure 3 allows the reflected beam to pass through the polarizing beam splitter 20 in a normally incident direction to the surface 28. The reflected beam strikes the position sensitive detector 30. This arrangement is useful, for example, in applications where mechanical clearance is limited, such as in measuring the lower disk surface on a spin stand. The measurements and relationships with regard to the signals from the position sensitive detector 30 remain the same as in the embodiment of Figure 1.

[27] The embodiments of the present invention provide an optical system for measuring the surface topography of ultra-smooth surfaces by using a normally incident beam deflection method. The arrangement reduces the test spot size and the beam deflection method, especially in comparison to previous arrangements. By employing a normally incident beam method and arrangement, the slope of ultra-smooth surfaces may be measured without the confounding effects of surface height change. Aspects of the invention provide for a device that is portable, cost-effective, and capable, as well as certain embodiments providing for a reduced overall device height.

[28] Although the present invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the scope of the present invention being limited only by the terms of the appended claims.